WITHIN-BAND DETECTOR-TO-DETECTOR CALIBRATION WITH MODIS EARTH VIEW DATA

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Objectives

The objectives of this approach are two-fold; firstly, to validate and refine within-band detector-to-detector inter-calibration; secondly, to validate and refine certain aspects of the pixel geolocation scheme. The second objective will concentrate on monitoring relative *effective* misalignments of within-band detectors. Apparent misalignments of this type may be caused by physical defects such as distortions of the optical field of view due to shifts in the optical components, as well as computational defects such as misdetermination of the initial sample acquisition from scan line to scan line.

Methodologies

The scan geometry of the MODIS mirror, in conjunction with the detector linear array, results in the so called "bow tie effect" as depicted in Figure 1. This figure portrays an idealized projection of pixel IFOV's on to the surface of the earth, to one side of nadir, for a ten detector array for two successive sweeps. Pixels at nadir appear along the left axis of this plot and the intersection of the pixel look angle on the surface appears at 1 degree increments, from 0 to 55 degrees, representing the full off-nadir look angle. At the current sampling rate of 1.418 mrads per look there are approximately 12 looks in one degree of scan therefore the spacing along scan lines of the pixel centers for each of the detectors are approximately 12 pixels. In this portrayal it is assumed that each array element projects to a 1 kilometer ground field of view (GFOV) at nadir. An examination of this figure shows that at some point during each scan detector 1 will successively look at the same target as viewed on the preceding scan by detectors 10, 9, 8, 7, and 6 respectively. Similarly, detector 2 will see the same target as on the previous scan for detector 10, 9, 8, and 7 and so on until we reach detector 5 which will be coincident , at the edge of its scan, with the same piece of real estate as detector 10 from the previous scan. The viewing conditions for these overlapping samples are also quite consistent. Since the satellite has only moved a very short distance, the sun angle is the same and the viewing angle changes by less than 1 degree. Notice that figure 1 portrays only half of the swath and that there are in fact two opportunities per scan for each coincident event.

It is proposed that these coincidences of view form the basis for performing a within-band detector-to-detector calibration. Figure 2 depicts coincident observations for a detector pair observing the same ground target twice per scan during a section of an orbit. Scattergrams, such as the one displayed in figure 2, present a direct display of the relationship between the radiometric responses of two detectors (generically identified here as detector A versus detector B) within the same band (i.e. on the same linear array). Although, not all detector pairs come into coincidence (e.g. detectors 2 and 3), there is sufficient over determination (e.g. both detector 2 and detector 3 come into coincidence with detectors 10,9 and 8) to mathematically infer relationships for all possible pairs.

Several factors conspire to prevent exact coincidence of observations for detector pairs. Sampling start time will vary from scan line to scan line, resulting in different pixel displacement from nadir for successive passes. In addition, pointing offset although hopefully predetermined, will not conform to the nominal specifications. If the geolocation of each observation is achieved with a prescribed accuracy of less than 0.1 pixel, it is anticipated that all pixel pair coincidences with an overlap exceeding a predetermined threshold (e.g. 75% areal overlap or greater) can be determined. These observations can then be used for the scattergram. A valid relationship between detector responses can be obtained if the variations in the overlap pattern due to varying scan offsets from sweep to sweep should lead to a randomized overlap orientation. In addition, the variations in landscape should help randomize the effect of systematic overlap orientations due to detector pointing offset from nominal values.

The net impact of all of this is that using heavily overlapped observations rather than completely coincident observations should not change the nature of the scattergrams under consideration, but should merely increase the scatter around the central relationship. obviously as the threshold is lowered the scatter around the idealized relationship will increase. A number of mathematical techniques are available to determine an analytic or semi-analytic (e.g. piecewise curve fitting) for expressing the interdetector response relationships. If the detector response is linear, a good approximation may be achieved by just doing a linear or a very low order fit.

The above technique is premised upon the ability to accurately geolocate each of the observations. If this is not the case, we may exploit the inherently higher correlation between well registered detectors (particularly in terrain varying on a kilometer scale) to validate and/or adjust the within-band detector-to-detector registration. The variance in a detector pair scattergram will increase as coincident observations for a detector pair become increasingly misaligned. If the nature of the *effective* misalignment results in random differences (usual case) between the radiative properties of the targets being observed by the respective detectors, the scattergram approach to within-band inter-detector relative calibration will still produce a valid relationship.

The degree of scatter (variance) of a within-band detector-to-detector scattergram of coincident observations for a portion of an orbit is dependent on both the degree of effective detector alignment and the degree of homogeneity of the landscape radiative properties for the orbit segment under consideration. Misalignment effects are amplified by landscapes which are inhomogeneous over at pixel scale sizes. It is clear that the variance of within-band detector-to-detector scattergrams constructed over such terrain is extremely sensitive to misregistration between the detectors.

Let us assume that, based on the geolocation calculations, we predict a coincidence between sample n for detector A on scan s (A_n^s) and sample m for detector B on the preceding scan (B_m^{s-1}). Now we may extract observation pairs A_n^s, B_m^{s-1} for all scans (i.e. all values of s) along an orbital segment. To simplify notation, this set of paired (coincident) observations will be referred to as A_n, B_m with the summation over s implied. To check for misalignment, we may construct the following series of, for example 9, scattergrams based on the predicted pair A_n, B_m :

(1) A_{n+i}, B_{m+j} for $-1 \leq i, j \leq +1$

In principle, the scattergram corresponding to i = j = 0 should display the least variance if the predicted coincidence geolocation is accurate. A consistent occurrence of the minimal variance at some other fixed value for and j implies a mislocation of the coincidence (i.e. an *effective* misalignment) by a substantial fraction of a pixel. In fact, if we define a set of paired observations as indicated in expression (1) above, an analyzing a large collection of these sets for the frequency distribution of the locations at which minimal variance occurs will reveal small subpixel misalignments.

Error budget

Since the technique described above is sensitive to changes in *effective* detector alignment, there is a great dependence on the ability to accurately geolocate the position of various observations along each of the scans for each detector. Locational accuracies of 0.1 pixel or less are required for accurate thresholding of pixel overlap areas as described in in the preceeding section. A potential major source of error is post launch misalignment of optics which cause apparent changes in detector pointing offsets as determined from prelaunch. measurements. In addition, it is required to know the phase delays along each scan line for acquisition of pixel data (exact position of pixels with respect to nadir will vary from scan line to scan line). Although mislocation resulting in selection of pixels which in fact are below threshold overlap values will result in increased variance, the actual calibration relationship should not change even if the geometric location error has a systematic component. Large systematic errors may lead to (several pixels) establishment of regionally erroneous relationships, particularly in areas where discontinuities aligned with the flight direction (e.g. coastline).

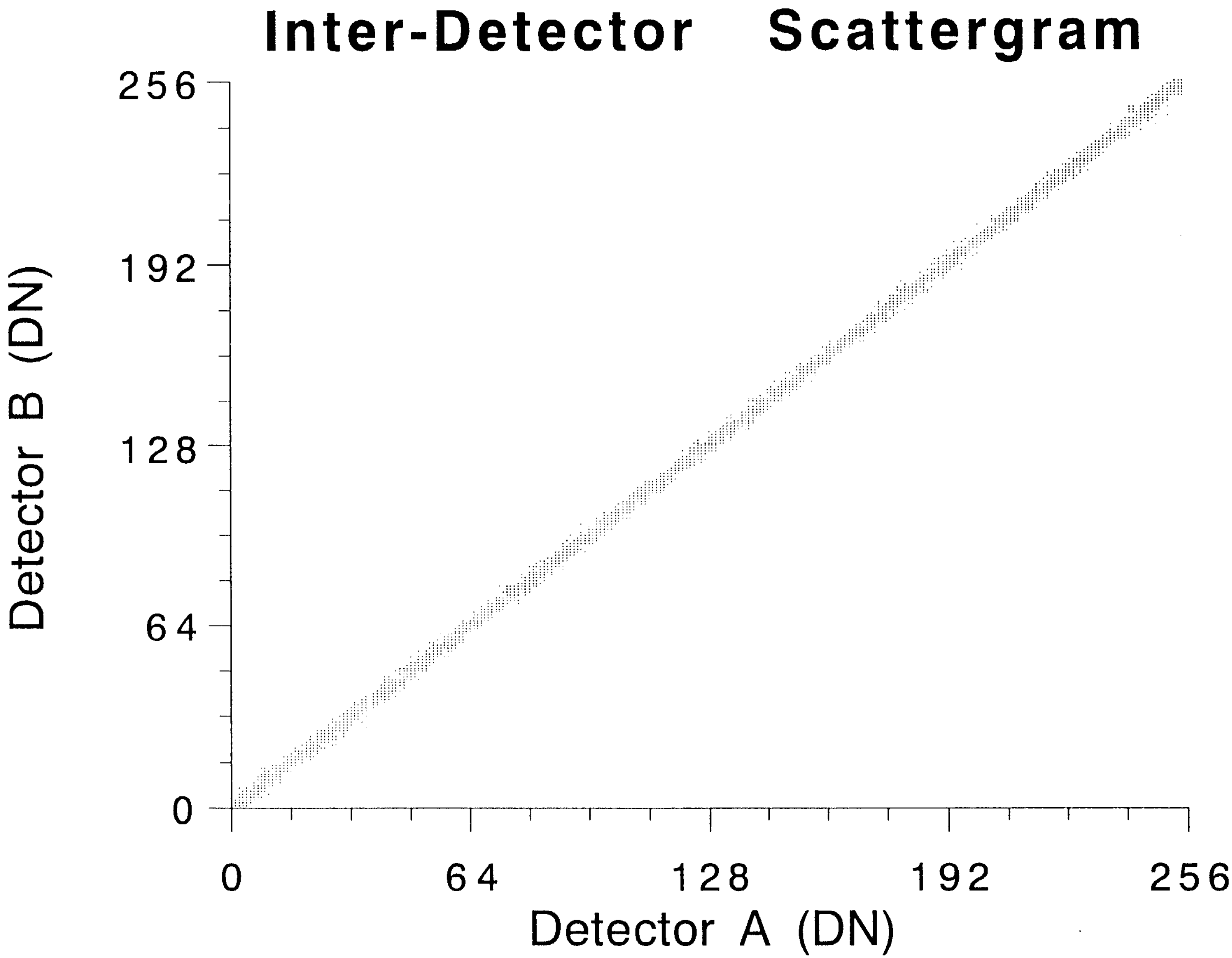
Establishing the best geometric alignment between pixels of the two detector positions rely on the premise that small scale variations contrast substantially varying over less than a pixel are characteristic of the landscape.

Validation

Techniques will be corroborated by taking as many measurements as possible from space view test data acquired prior to launch and comparing results with those computed from prelaunch radiometric and geometric calibration. In addition, technique will be tested on a variety of synthetic scenes created with radiometric variance at a variety of characteristic scale lengths.

Calibration sites

During the post launch phase, data will be captured for all detector pairs that meet the threshold criteria as outlined above. However, particular attention will be paid to known homogeneous areas and/or conditions (e,g, uniform cloud cover) for determining the radiometric within-band detector-to-detector calibration. Verification of the geolocation will be carried out over areas of the globe where it is anticipated that small scale high contrast variations are most likely to occur.


Inter-Detector Scattergram
256
192
128
64
0
Detector B (DN)
0
64
128
192
256
Detector A (DN)